Appendix E
Computer Programs

MACE PROGRAMS

MACE (Micro Computer Applications for Coastal Engineering) programs are described in CETN-VI-16 (Jones 1989), and may be obtained from the Engineering Computer Programs Library Section, Technical Information Center, US Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS, 39180-6199.

BWCOMP calculates breakwater volumes and costs, demonstrating the effect of varying breakwater slopes on wave transmission, the choice of armor size and shape, and overall volume.

BWDAMAGE estimates expected damage and life cycle costs of related maintenence and repairs of a rubblemound breakwater.

BWLOSS1 estimates economic losses due to wave attack as a function of wave height. The program optionally provides an estimate of expected annual economic losses due to wave probability distribution of significant wave heights.

BWLOSS2 fits a long-term cumulative probability distribution to transmitted wave height data and estimates expected annual economic losses due to wave attack after a protective breakwater has been built.

DUNE predicts storm-induced dune erosion given an initial profile shape, storm surge level, sediment size, and a wave height.

FWAVOCUR determines how frequently extreme wave conditions are expected over a specified time period.

HURWAVES estimates the maximum gradient wind speed, the maximum sustained wind speed, the maximum significant wave height, and the maximum significant wave period for slow-moving hurricanes.

TIDEC estimates the tidal current speed at any time based on the predictions of the National Oceanic and Atmospheric (NOAA) tidal current tables.

TIDEHT estimates the elevation of the water surface at any time or the time at increments of elevation based on the predictions of NOAA tide tables.

WAVDIS1 estimates the parameters of the three commonly used extremal probability distributions for prediction of extreme wave conditions.

WAVDIS2 is an alternate version of WAVDIS1 that estimates the parameters by the method of moments.

ACES PROGRAMS

ACES (Automated Coastal Engineering System) is a microcomputer-based design and analysis system in the field of coastal engineering. The contents range from simple algebraic expressions both theoretical and empirical in origin, to numerically intense algorithms spawned by the increasing power and affordability of computers. ACES is described in CETN-VI-20 and by Leenknecht and Szuwalski (1988). Copies of ACES programs may be obtained from US Army Engineer Waterways Experiment Station, ATTN: CEWES-IM-MI-S, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

Windspeed Adjustment and Wave Growth
The methodologies represented in this ACES application provide quick and simple estimates for wave growth over open-water and restricted fetches in deep and shallow water. Also, improved methods (over those given in the Shore Protection Manual (SPM) 1984) are included for adjusting the observed winds to those required by wave growth formulas.

Beta-Rayleigh Distribution
This application provides a statistical representation for a shallow water wave height distribution. The Beta-Rayleigh distribution is expressed in familiar wave parameters: the energy-based wave height, peak spectral wave period, and water depth. After constructing the distribution, other statistically based wave height estimates such as the root-mean-square height, mean wave height, and average of the highest one-tenth wave heights can be easily computed.

Extremal Significant Wave Height Analysis
This application provides significant wave height estimates for various return periods. Confidence intervals are also provided. The approach developed by Goda (1988) is used to fit five candidate probability distributions to an input array of extreme significant wave heights.

Constituent Tide Record Generation
This application predicts a tide elevation record at a specific time and locale using known amplitudes and epochs for individual harmonic constituents.

Linear Wave Theory
This application yields first-order approximations for various parameters of wave motion as predicted by the wave theory bearing the same name (also known as small amplitude, sinusoidal, or Airy theory). It provides estimates for common items of interest such as water surface elevation, general wave properties, particle kinematics, and pressure as functions of wave height and period, water depth, and position in the wave form.

Cnoidal Wave Theory
This application yields various parameters of wave motion as predicted by first-order (Isobe 1985) and second-order (Hardy and Kraus 1987) approximations for Cnoidal wave theory. It provides estimates for common items of interest such as water surface elevation, general wave properties, kinematics, and pressure as functions of wave height and period, water depth, and position in the wave form.

Linear Wave Theory with Snell's Law
This application provides a simple estimate for the transformation of monochromatic waves. It considers two common processes of wave transformation: refraction (using Snell's law) and shoaling using wave properties predicted by linear wave theory (Airy 1845). Given wave properties and a crest angle at a known depth, it predicts the values in deep water and at a subject location specified by a new water depth. An important assumption is that all depth contours are assumed to be straight and parallel.

Combined Diffraction and Reflection by a Vertical Wedge
This application estimates wave height modification due to combined diffraction and reflection near jettied harbor entrances, quay walls, and other such structures. Jetties and breakwaters are approximated as a single straight, semi-infinite breakwater by setting the wedge angle equal to 90 degrees. Additionally, such natural diffracting and reflecting obstacles as rocky headlands can be approximated by setting a particular value for the wedge angle.

Irregular Wave Transformation (Goda's method)
This application yields cumulative probability distributions of wave heights as a field of irregular waves propagate from deep water through the surf zone. The application is based on two random-wave theories by Goda (1975, 1984). The application combines the two theories, by shoaling and refracting random waves over a plane bottom with straight and parallel contours. The theories assume a Rayleigh distribution of wave heights in the nearshore zone and a Bretscheneider-Mitsuyasu incident directional spectrum. The processes modeled include: wave refraction, wave shoaling, wave breaking, wave setup, and surf beat.

Breakwater Design Using Hudson and Related Equations
This application provides estimates for the armor weight, minimum crest width, armor thickness, and the number of armor units per unit area of a breakwater using Hudson and related equations.

Toe Protection Design
This application determines armor stone size and width of a toe protection apron for vertical face structures such as seawalls, bulkheads, quay walls, breakwaters, and groins. Apron width is determined by the geotechnical and hydraulic guidelines specified in EM 1110-2-1614. Stone size is determined by a method (Tanimoto, Yagyu, and Goda 1982) whereby a stability equation is applied to a single rubble unit placed at a position equal to the width of the toe apron and subjected to standing waves.

Nonbreaking Wave Forces at Vertical Walls
This application provides the pressure distribution and resultant force and moment loading on a vertical wall caused by normally incident, nonbreaking, regular waves. The results can be used to design vertical structures in protected or fetch-limited regions when the water depth at the structure is greater than about 1.5 times the maximum expected wave height. The application provides the same results as found using the design curves given in Chapter 7 of the SPM (1984).

Rubble Mound Revetment Design
Quarrystone is the most commoly used material for protecting earth embankments from wave attack because, where high-quality stone is available, it provides a stable and unusually durable revetment armor material at relatively low cost. This ACES application provides estimates for revetment armor and bedding layer stone sizes, thicknesses, and gradation characteristics. Also calculated are two values of runup on the revetment, an expected extreme and a conservative runup value.

Irregular Wave Runup on Beaches
This application provides an approach to calculate runup statistical parameters for wave runup on smooth slope linear beaches. To account for permeable and rough

slope natural beaches, the present approach needs to be modified by multiplying the results for the smooth slope linear beaches by a reduction factor. However, there is no guidance for such a reduction due to the sparsity of good field data on wave runup. The approach used in this ACES application is based on existing laboratory data on irregular wave runup (Mase and Iwagaki 1984, and Mase 1989).

Wave Runup and Overtopping on Impermeable Structures

This application provides estimates of wave runup and overtopping on rough and smooth slope structures which are assumed to be impermeable. Runup heights and overtopping rates are estimated independently or jointly for monochromatic or irregular waves specified at the toe of the structure. The empirical equations suggested by Ahrens and McCartney (1975), Ahrens and Titus (1985), and Ahrens and Burke (1987) are used to predict runup, and Weggel (1976) to predict overtopping. For irregular wave conditions the runup caused by these conditions is assumed to have a Rayleigh distribution (Ahrens 1977). The overtopping rate is estimated by summing the overtopping contributions from the individual runups.

Wave Transmission on Impermeable Structures

This application provides estimates of wave runup and transmission on rough and smooth slope structures. It also addresses wave transmission over impermeable vertical walls and composite structures. In all cases, monochromatic waves are specified at the toe of a structure that is assumed to be impermeable. For sloped structures, a method suggested by Ahrens and Titus (1985) and Ahrens and Burke (1987) is used to predict runup, while the method of Cross and Sollitt (1971) as modified by Seelig (1980) is used to predict overtopping. For vertical wall and composite structures, a method proposed by Goda, Takeda, and Moriya (1967) and Goda (1969) is used to predict wave transmission.

Wave Transmission Through Permeable Structures

This application determines wave transmission coefficients and transmitted wave heights for permeable breakwaters with crest elevations at or above the still-water level. This application can be used with breakwaters armored with stone or artificial armor units. The application uses a method developed for predicting wave transmission by overtopping coefficients using the ratio of breakwater freeboard to wave runup (suggested by Cross and Sollitt 1971). The wave transmission by overtopping prediction method is then combined with the model of wave reflection and wave transmission through permeable structures of Madsen and White (1976).

Longshore Sediment Transport

This application provides estimates of the potential longshore transport rate under the action of waves. The method used is based on the empirical relationship between the longshore component of wave energy flux entering the surf zone and the immersed weight of sand moved (Galvin 1979). Two methods are available to the user depending on whether available input data are breaker wave height and direction or deep water wave height and direction.

Numerical Simulation of Time-Dependent Beach and Dune Erosion

This application is a numerical beach and dune erosion model that predicts the evolution of an equilibrium beach profile from variations in water level and breaking wave height as occur during a storm. The model is one-dimensional (only onshore-offshore sediment transport is represented). It is based on the theory that an equilibrium profile results from uniform wave energy dissipation per unit volume of water in the surf zone. The general characteristics of the model are based on a model described by Kriebel (1982, 1984a, 1984b, 1986). Because of the complexity of this methodology and the input requirements, familiarization with the references listed is strongly recommended.

Calculation of Composite Grain Size Distributions

The major concern in the design of a sediment sampling plan for beach fill purposes is determining the composite grain size characteristics of both the native beach and the potential borrow site. This application calculates a composite grain size distribution that reflects textural variability of the samples collected at the native beach or the potential borrow area.

Beach Nourishment Overfill Ratio and Volume

This application provides two approaches to the planning and design of beach nourishment projects. The first approach is the calculation of the overfill ratio, which is defined as the volume of actual borrow material required to produce a unit volume of usable fill. The second approach is the calculation of a renourishment factor which is germane to the long-term maintenance of a project, and addresses the basic question of how often renourishment will be required if a particular borrow source is selected that is texturally different from the native beach sand. The methods described can be found in James (1975) and the SPM (1984).

A Spatially Integrated Numerical Model of Inlet Hydraulics
This application is a numerical model which estimates coastal inlet velocities, discharges, and bay levels as functions of time for a given time-dependent sea level fluctuation. Inlet hydraulics are predicted in this model by simultaneously solving the time-dependent momentum equation for flow in the inlet and the continuity equation relating the bay and sea levels to inlet discharge. The model is designed for cases where the bay water level fluctuates uniformly throughout the bay and the volume of water stored in the inlet between high and low water is negligible compared to the prism of water that moves through the inlet. The model has been previously described by Seelig (1977) and Seelig, Harris, and Herchenroder (1977) for use on large computers.

CMS

The Coastal Modeling System (CMS) is a user-friendly, supercomputer-based system of models and supporting software packages described in CETN VI-18 (Mark 1990) and by Cialone et al. 1992. CMS incorporates models that are computationally and memory intensive for transfer to the Corps elements. Software packages for supporting the CMS models include grid generation software, post-processing software to display model results, utility software to supplement data used by the models, and automated Job Control Language (JCL) procedures to execute these functions.

WIFM (Cialone et al. 1992). The US Army Corps of Engineers Waterways Experiment Station (WES) Implicit Flooding Model (WIFM) solves the vertically integrated Navier-Stokes equations in stretched Cartesian coordinates. The model simulates shallow-water, long wave hydrodynamics such as tidal elevations and currents, storm surges, and tsunami propagation. WIFM contains many useful features for studying phenomena such as moving boundaries to simulate flooding/drying of low-lying areas and subgrid flow boundaries to simulate small barrier islands, jetties, dunes, or other structural features. The model may be driven at the outer boundary by tide elevation, flow velocities, uniform flux, or inverted barometer effects. WIFM also accepts wind fields for including the effects of wind stress during hurricanes or other strong storm systems.

SPH (Cialone et al. 1992). The Standard Project Hurricane (SPH) numerical model represents wind and atmospheric pressure fields generated by hurricanes. It is based on the Standard Project Hurricane criteria developed by the National Oceanic and Atmospheric Administration (NOAA), and the model's primary output are hurricane-generated wind fields which can be used in storm surge modeling. It can be run separately, or invoked from within the model WIFM.

RCPWAVE (Ebersole, Cialone, and Prater 1986). The Regional Coastal Processes Wave (RCPWAVE) propagation model is a two-dimensional, steady state, short wave model for solving wave propagation problems over an arbitrary bathymetry. The governing equations solved in the model are the "mild slope" equation for linear, monochromatic waves, and the equation specifying irrotationality of the wave phase function gradient. These equations account for shoaling, refraction, and bottom-induced diffraction within a study area, and also contain a wave breaking scheme.

CLHYD (Cialone et al. 1992). The Curvilinear Longwave Hydrodynamic (CLHYD) model is a two-dimensional, depth-averaged model for computing tidal circulation and storm surge propagation. It is a finite difference model developed in boundary-fitted (curvilinear) coordinates. The model solves finite difference approximations of the Navier-Stokes (continuity and horizontal momentum) equations for the water surface displacement and the unit flow rate components. CLHYD can simulate flow fields induced by wind fields, river inflows/outflows, and tidal forcing. The model should be used where shallow-water wave theory applies (water depth is sufficiently small when compared with wavelength).

HARBD (Chen and Houston 1986). The Harbor-Deep (HARBD) model is a two-dimensional, steady state, finite element model for studying wave oscillations in and around harbors, and is applicable to harbors having arbitrary depths and geometric configurations. This model is based on linear wave theory, and solves a boundary value problem of harbor resonance and wave scattering which includes the effects of bottom friction. The model may also be applied to weakly nonlinear waves, though great care must be exercised while interpreting results.

SHALWV (Hughes and Jensen 1986, Cialone et al. 1992). The Shallow Wave (SHALWV) model is a two-dimensional, pseudo-discrete, time dependent spectral wave model for simulating wave growth, decay, and transformation. Developed in a rectangular Cartesian coordinate system, the model is based on the solution of the inhomogeneous energy balance equation via finite difference methods. This equation accounts for several mechanisms, including wind-wave growth, refraction, shoaling, nonlinear wave-wave interaction, high frequency energy dissipation, surf zone breaking and decomposition of energy into wind-sea and swell wave components. Model output includes one-dimensional frequency and two-dimensional frequency directional spectrums.

STWAVE (Cialone et al. 1992). The numerical model STWAVE is a nearcoast, time-independent spectral wave energy propagation model. The model solves the spectral energy balance equation (including refraction, shoaling, and wave breaking) using finite-difference methods. This steady-state model simulates wave propagation over a spatial area assuming wave conditions vary sufficiently slowly. The variation of waves at a given point may be neglected relative to the time required for waves to pass across the computational grid if the model is limited to nearcoast applications in which waves move quickly across the grid (within 30 minutes).

SMS

The Shoreline Modeling System (SMS) is a microcomputer-based software package that contains a collection of generalized computer programs assembled to enable the user to perform complete longshore sediment transport processes and shoreline evolution assessments (Gravens 1991). The SMS contains two major coastal process numerical models: GENESIS and RCPWAVE (see discussion in CMS section); twelve system-support programs for data preparation, analysis, and numerical model input generation; one general purpose graphics program; and two special purpose editors for generation or modification of model configuration input files. The system-support programs were specifically developed to automate and standardize the typical data preparation and analysis tasks encountered in the course of conducting a shoreline evolution study, beginning with the user's original data source and concluding with input data sets (files) for GENESIS.

GENESIS (Hanson and Kraus 1989; Gravens, Kraus, and Hanson 1991). The Generalized Model of Shoreline Change (GENESIS) model was developed to assess impact of shoreline structures or determine littoral budgets. The model can include an arbitrary number of groins, jetties, detached breakwaters, seawalls, beach fills and river discharges; diffraction at detached breakwaters, jetties and groins; multiple wave trains from independent sources; and sand transport due to oblique wave incidence and longshore gradient in wave height.

RCPWAVE (see previous discussion under CMS heading).

CORPS OF ENGINEERS NUMERICAL MODELS

Other Corps of Engineers numerical mainframe and personal computer models which may be of use in coastal planning and engineering studies are described below.

NMLONG (Kraus and Larson 1990, Larson and Kraus 1991). The Numerical Model of the Longshore current (NMLONG) calculates the distribution of the longshore current for almost arbitrary wave and beach conditions. Both the wave and wind-induced longshore current and wave height distribution for multiple bar and trough bathymetry and given wave conditions are computed, and a plot is generated to show results.

ON_OFF (Kraus 1991). ON_OFF is a personal computer program that determines the likelihood for erosion or accretion given a beach with a given grain size, under certain wave height and period conditions. The program predicts erosion or accretion in terms of "highly probable" and "probable" qualifiers.

SBEACH (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). The Storm-Induced model of Beach Change (SBEACH) is an empirically based two-dimensional model that simulates cross-shore sediment transport due to storm events, and post-storm profile recovery. It was developed for sandy beaches with uniform representative grain sizes in the range of 0.20 to 0.42 mm. SBEACH accepts as input varying water level as produced by storm surge and tide, varying wave height and period, and arbitrary grain size in the fine to medium sand range. The model simulates bar formation during storms, and subsequent beach recovery with berm buildup.

WISTRT (Gravens 1989). WISTRT provides calculations of potential longshore sand transport rates using Wave Information Study (WIS) Phase III hindcast wave estimates. Refraction and shoaling of incident linear waves are calculated using Snell's law and conservation of wave energy flux. A shallow-water wave breaking criterion defines wave properties at the break point, and potential longshore sand transport rates are calculated by means of the energy flux method in the SPM (1984).

REF/DIF (Kirby and Dalrymple 1986, Dalrymple et al. 1984). REF/DIF is a combined refraction/diffraction monochromatic wave propagation model based on Booij's (1981) parabolic approximation for Berkoff's (1973) mild slope equation, where reflected waves are neglected. The model is valid for waves propagating within 60 degrees of the input direction, and is based on Stokes perturbation expansion. In order to have a model that is valid in shallow water outside the Stokes range of validity, a dispersion relationship which accounts for the nonlinear effects of amplitude is used. Wave breaking is simulated using Kirby and Dalrymple's (1986) dissipation scheme, and boundaries such as coastlines and islands are modeled using the thin film approximation where the surface piercing feature is replaced by shoals with very shallow depth (less than 0.1 depth units).